BOE

Working example from LBNF/DUNE CD1 Review

Basis of Estimate

Slide shown to CD1 review committee

(BOEs and supporting material in separate file)

BOE Backup Report

Schedule

Supporting Document

BOE Form

LBNE Long-Baseline Neutrino Experiment Document 10596-v10

130.05.04.02.04 TPC APA Construction

Abstract:
Basis of Estimate for the Far Detector

Files in Document:

- 130.05.04.02.04 Backup Report (10596.xlsx, 1.1 MB)
- 130.05.04.02.04 Schedule (BOE Schedule Report 10596.pdf, 84.3 kB)
- BOE Supporting Document (Worksheet_TPC_APA_Const 2015 v4 2015Jul 1.xlsx, 3.0 MB)
- BOE for 130.05.04.02.04 TPC APA Construction (APA DUNE BOE vJul.docx, 24.1 kB)
- Quotes 1-5 (Reference No. 1-5.pdf, 321.5 kB)
- Quotes 16, 17 (Reference No. 16,17,34,33.pdf, 505.1 kB)
- Quotes 18-32 (Reference No. 18-32.pdf, 2.3 MB)
- Quotes 9-15 (Reference No. 9-15.pdf, 614.8 kB)

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Topics:

- Project Management:Cost Estimate:BOE-LAr

Authors:

- B. Paulos

Keywords:
BOE Far Detector

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LBNE Long-Baseline Neutrino Experiment Document 10596-v10

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LBNE-doc-10596-v2

Docdb document 

BOE form level X 

Totals in .doc form, our current BOE format

Pivot table from P6

Cost summaries of all WBS at level X, .xlsx

Worksheet

Custom excel with many tabs
- ✓ Calculations
- ✓ BOM (bill of materials)
- ✓ Activities
- ✓ gifs of quote docs

Quote docs

Miscellaneous formats

BOE form
Level X

10596-

130.05 DUNE
BASIS of ESTIMATE (BoE)
for
130.05.04.02.04 TPC Anode Plane Assemblies Construction

Date of Estimate: March 31, 2015

Prepared by: Bob Paulos

Contributing Authors: Bo Yu and Lee Greenler

Reviewed by: Jim Stewart

Docdb #: 10596

WBS number: 130.05.04.02	**WBS Title: TPC Anode Plane Assemblies Construction**	**Control Account: _____**

WBS Dictionary Definition:
Design, construction and testing of the Anode Plane Assemblies (APA's) and shipment to the far detector site for installation. Installation is covered in a separate WBS. The components will be built in conjunction with international partners.

Supporting Documents (including but not limited to):
see Electronic BOE file (docdb 10596) for supporting documentation.

Details for this BOE are shown in the APA Construction BOE Worksheet, 3/30/2015 (docdb 10596)

Assumptions:
This BOE is for design, construction and test of APAs and the necessary equipment to build them. The effort shown here relies heavily on the CERN test activity – much of the procedure development and R&D sufficient to produce APAs that meet requirements will be executed as part of the CERN test development.

To maintain construction schedule, we assume that two sites will be utilized in the production of APAs. One site will be at the University of Wisconsin – PSL and the other is TBD. Each site will use identical fabrication and test procedures and equipment and tooling. This will minimize cost and provide uniformity in APA performance

Details of the Base Estimate:

This estimate is for the design, construction, and testing of Anode Plane Assemblies. It covers the labor force and equipment for each step of the design, fabrication and acceptance test sequence.

APAs are a key component of the Time Projection Chamber (TPC) assembly. Pairs of APAs will be linked and assembled into three rows of 25. Cathode planes separate the APA rows and are surrounded by a Field Cage Assembly.

To maintain the construction schedule, two fabrication facilities with identical tooling and winding equipment will be utilized and are estimated here. 150 total APAs are required, 75 per construction site. They will be produced at an average rate of 50 per year. Construction starts in January 2020. This will allow for enough APA availability to start TPC installation in the cryostat underground toward the end of CY2021.

Design Summary:

	Engineer/Physicist	Design Tech	Shop	M&S	Travel
Preliminary Design	2590	2340		$52,000	$15,600
Prototype and Mockups	784		1252	$20,800	$5,200
Final Design	3240	2240		$54,496	$19,760
Pre-Production Prototype				$260,000	
Totals	**6614**	**4580**	**1252**	**$387,296**	**$40,560**

BOE form
Level X

10596-

Production Summary:	M&S	welder [hr]	machinist [hr]	tech [hr]	labor total [hr]
	$2,530,998	6000	30640	45000	81640

Supervision	Manufact. Engr.	Mech Engr	Physicist	travel	labor total (hr)
	6000	2000	1000	25,000	9000

Labor:

For construction this BOE assumes that two facilities with experience in building high reliability equipment in production quantities are available. The labor mix requires that experienced shop personnel (welders and instrument makers), mechanical engineers, and physicists are available. A key position and assumption in this BOE is the manufacturing engineer. This position will be a full-time experienced engineer that is familiar with APA construction techniques as well as manufacturing methods.

M&S:

Each construction site will require a dedicated clean space of approximately 15,000 square feet. Overhead crane coverage will be needed over some of this space with overhead clearance of approximately 5 m.

A large quantity procurement will be made of stainless steel tubing for frame construction. A vendor survey has already been performed and is likely to be repeated prior to procurement of the production lot. A tube selection process has been drafted based on past prototyping efforts.

A 40 percent scale prototype APA has been built at UW/PSL. Four smaller APAs for the the 35T test at FNAL have also been built and tested. This BOE is informed by that experience.

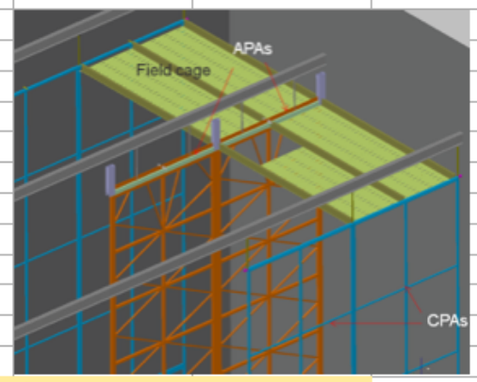
Contingency:

At this level of design maturity contingency on these estimates should be 40 percent on labor and 40 percent on materials.

APA_Worksheet | APA_BOM | APA_Procedures | APA_Quotes

TABS

APA Construction BOE Worksheet 7/1/2015					Note, this is only valid for the current ~4.8 mm wire pitch within an APA plane (3 mm pitch would substantially increase some costs)									
Production Preparation				M&S [$]	Travel [$]	Engineer [hr]	Designer [hr]	M.Tech [hr]	Machinist [hr]	Electrician [hr]	Labor total [h	Physicist [hr]		
	Review APA assembly plan				4,000	40					40	80		
	Setup the assembly area			50000		160		640	160	80	1040			
APA Parts Procurement														
	Prep APA parts req for Cryo #1			4,013,434		160		80			240			
Production of 150 APAs for one 10kT cryostat														
	Production Sur	M&S	welder [hr]	machinist [hr]	tech [hr]	abor total [hr]		Supervision	Manufact. Engr.	Mech Engr	Physicist	travel	abor total (hr)	
		$4,013,434	6000	30640	45000	81640			6000	2000	1000	25,000	9000	
		TPC major parameters												
		APA active width:			230	cm								
		APA active height:			598	cm								
		Drift length:			360	cm	center to center APA-CPA							
		Number of readout channels			2,560									
		Number of APAs / cryostat			150									
		Number of CPAs / cryostat			100									
		Total field cage area/cryostat:			3,105	sq. m								



Major Item	Minor Item	Task Description	Material Cost ($)	Labor (days)	Labor Type	Comments
APA (each) See Reference PDFs for current cost detail from invoices			26,756	68.0		2.3m x 6m x 150 modules
	SS frame					
		Material cost:	2,798			See BOM sheet
		Cutting & Drilling		7.0	machinist	
		Welding		5.0	welder	
		Straightening/cleaning		3.0	machinist	
	Beryllium copper wires 150µm, 24.5 km		1,287			See BOM sheet
	Wire mesh		311			See BOM sheet
	FR4 boards					
		wire support combs	2,799	1.5	machinist	See BOM sheet
		comb mount strips, connector card supports	201			See BOM sheet
		top wire bonding boards	5,000	2.0	machinist	See BOM sheet
		long side wire bonding boards	2,010	4.5	machinist	See BOM sheet
		non-readout end wire bonding boards	946	4.0	machinist	See BOM sheet
		pins and sockets for boards	4,149			See BOM sheet
		capacitors	2,580			See BOM sheet
		edge and end board G10 covers	132			See BOM sheet
	Electronics cover		171	2.0	machinist	See BOM sheet
	Bubble guides beneath cover		16			See BOM sheet
	solder	fixing BeCu wire to boards	884			See BOM sheet
	epoxy	7 DUO-Pak 43ml cartridges/APA	170			J Heise cost summary
	hookup wire (tinned copper in teflon insulation)		50			engr judgment
	teflon spiral wrap		100			engr judgment
	fasteners		878			See BOM sheet
	Wire frame assembly					2 person crew

Formulas

APA frame		In this sheet, color background cells are formula results												
	Frame components							feature descriptions not updated--KWK 6/11/15						
		stainless steel 304								holes		tapped holes		
		3"x4"x1/8"x 19.9' tubes		2	pcs			4" x 3/4" slots x10		20		110		
		3"x4"x1/8"x 19.2' tubes		1	pc			4" x 3/4" slots x20						
		3"x4"x1/8"x ~92" tubes		2	pcs									
		3"x2"x1/8"x 3.3' tubes		8	pcs					10		10		
		Frame interface plates: 5' of 0.5x3" rect, 5' of 0.625x3"		1	lot									
		frame joint shims (1 per jt assumed)		1	lot									
		frame joint fasteners, qtys & types per PSL dwg 8752D600 05/22/2015		1	lot									
		frame rivet nuts		12	ea									
		weld filler wire		0.32	lb									
		cleaning supplies for incoming metal												
		9"x91" x 1/4" sheet		1	pc					4		40		
APA BeCu wire														
		150 µm diameter, 24.5 km per APA, 9940 ft/lb, $160.5/lb, plus $400 setup fee per batch, assumed 5 batches		24.5	km									
APA wire mesh														
	Gantois wire mesh													
		use from 1.38m wide roll		33.1	sq m									
	Solder													
		49mg / pad; 9.15 lb calculated		9.15	lb									
	FR4 rectangles													
		comb mount strips		8	lengths									
		connector card support strips		2	runs									
	Fasteners													
		board fasteners		230	ea									
		board pins		40	ea									
		plating services for below		1	lot									
		photon detector mounting screws		1	lot									

Assembly Steps	
1	Construct the APA Frame
1.1	Cut the SS tubes to length
1.2	Drill and tap all holes on the APA frame
1.3	Machine the slots on the middle APA frame for the light guides
1.4	Weld the APA frames together using the pre-fabed welding fixture
1.5	Surface/grind the weld joints flat on the two sides facing the wire planes
1.6	Correct warpage on the frame
1.7	Clean the frame
2	Install the light guide system
2.1	Thread the photo detector cables through the APA frame to their designed locations; install the photo detector front-end readout board.
2.2	Insert the light guide assemblies into the slots in the APA frame, and fasten the light guide frames onto the APA
2.3	Connect the cables from the front-end readout board to the photo detector bases
2.4	Place the APA in a light tight enclosure, and perform calibration test
3	Install wires on the APA
3.01	install 10 photon detector mounts, and the 10 photon detectors, route the cables out to a corner of the APA, test photon detectors under a dark cover.
3.1	install the X wire support combs on the side of each 2" SQ tubes
3.2	stretch a sheet of wire mesh between the 2" SQ tubes. The edge of the mesh touching the wire combs is folded down and held by a strip of SS304. Check electrical continuity between the APA and the mesh. The other 3 edges are glued onto the face of the 2" SQ, or 2"x4" SS tube
3.3	Install X plane wire bonding boards on the top and bottom edges of the APA. Attached the dummy wire pitch bars on the readout edge of the APA to facilitate wire winding
3.4	Mount the APA onto the X & G plane wire winding machine, and wind the x wires
3.5	Glue the x wires down on the top and bottom wire bonding boards. Install the wire support combs for the V plane
3.6	Wait for the epoxy to cure
3.7	Solder the wires onto the corresponding solding pads on the top bonding boards, clean the solder flux
3.8	Install the V wire bonding boards on all four sides of the frame
3.9	Mount the APA onto the U & V plane wire winding machine, and wind the V wires
3.10	Glue the V wires down on the wire bonding boards. Install the wire support combs for the U plane
3.11	Wait for the epoxy to cure
3.12	Solder the wires onto the corresponding solding pads on the top, and side bonding boards, clean the solder flux
3.13	install the U wire bonding boards on all four sides of the frame
3.14	Mount the APA onto the U & V plane wire winding machine, and wind the U wires
3.15	Glue the U wires down on the wire bonding boards. Install the wire support combs for the G plane
3.16	Wait for the epoxy to cure
3.17	Solder the wires onto the corresponding solding pads on the top, and side bonding boards, clean the solder flux
3.18	install the G wire bonding boards on the top and bottom sides of the frame
3.19	Mount the APA onto the X & G plane wire winding machine, and wind the G wires